DEVICE AND METHOD FOR PREDISTORTING AN INPUT SIGNAL

Technical Field

The present invention relates to a device and a method for predistorting an input signal at an amplifier

.5   means of a transmitter chain. In particular, the invention relates to the compensation of phase jumps in the output power of an output signal caused by the changing of the power level of the output signal.

10   ## Description of Related Art

In mobile communication several techniques for transmitting information from a mobile terminal, such as a mobile telephone, a pager, a communicator, i.e. an electronic organizer, a smartphone or the like, to a base

15   station are available. The communication techniques include e.g. frequency division multiple access (FDMA), time division multiple access (TDMA), and code division multiple access (CDMA). One communication technology being based on the CDMA technology is the wideband code division multiple

20   access (WCDMA) currently being employed for the universal mobile telecommunication system (UMTS) being developed within the third generation partnership project (3GPP).

In CDMA systems the over-the-air power control of the channel between the mobile terminal and the base station is

25   a vital issue. An UMTS base station averages many channel estimates from a signal sent in different slots from a transmitter of a mobile terminal when it is possible, such as when the mobile is not moving or is moving very slow. This will give a large improvement of performance since the

30   pilot symbol comprised in each slot of the signal from the mobile terminal is always very weak. One requirement for this to work is that the channel remains substantially constant despite that the mobile terminal changes its output power. The environment of the mobile terminal, and

35   the distance between the mobile terminal and the base

station effects the power level of the signal received by
the base station. Also, the power received by the base
station is dependent on the wanted data rate in the up-
link. Therefore, the output power from the transmitter of

5   the mobile terminal is changed for meeting the requirement
that the power of the up-link channel from the mobile
terminal should remain substantially constant when received
by a base station. To provide the changing of the output
power of the transmitter of the mobile terminal, said

10   transmitter comprises an amplifier having variable gain.
The gain of the variable gain amplifier may be changed in
levels, so as to adjust the power of the output signal from
the transmitter of the mobile terminal according to certain
predetermined levels.

15   It has turned out that changing the output power of
the variable gain amplifier is difficult without affecting
the phase of the transmitted signal. Waveform generators
known in the art generating the input signal to the
variable gain amplifier can not compensate for phase jumps

20   being synchronized with the output power change, which e.g.
is described in the 3GPP specification TS 25.101. The link
performance, i.e. the link between the mobile terminal and
the base station, is degraded by the phase shift in the
transmitter of the mobile terminal. Therefore, it is

25   preferred to keep the phase-shift of the output power as
low as possible when changing the power level.

        Summary of the Invention
        It is an object of the invention to provide a device

30   for compensating for phase-shifts in the output power of an
output signal from a transmitter chain of an electronic
equipment, such as a mobile terminal, a mobile telephone, a
pager, or a communicator, said phase-shifts occurring as
time discrete phase-jumps in response to changing the

35   output power of the output signal. Another object of the

invention is to provide a device capable of compensating
for temperature dependent phase-shifts of the output power.
Still another object of the invention is to provide a
device capable of compensating for frequency or frequency
band dependent phase-shifts of the output power. Also, it
is an object of the invention that the compensation of the
phase-shift will not be detrimental to the output power.

A device comprising a storage means and a phase
offset adding means connected to a controller means
achieves the above objects. The controller means is adapted
to retrieve phase change values stored in a look-up table
of the storage means. Based on first and second phase
change values corresponding to a current and a new gain
level of an amplifier means, the controller means is
adapted to calculate a phase offset value. A signal
comprising the phase offset value is supplied to the phase
offset adding means, which is adapted to add the phase
offset value to an input signal at the amplifier means.

In one embodiment, the phase offset signal is a
complex value having a phase value corresponding to the
calculated phase offset value. By synchronizing the adding
of the phase offset signal to the input signal with the
changing of the gain level of the amplifier means in a time
gap between slots, wherein information data is transmitted,
the adding of the phase offset signal will not be
detrimental to the output power. The input signal is a base
band signal generated by a waveform generator. The phase
offset adding means of the device according to the
invention is in one embodiment provided after first and
second transmit filters of the waveform generator.

In another embodiment, said phase offset adding means
is provided prior to said filters of the waveform
generator. Further, the controller means is further adapted
to receive an indication that the gain level of the
amplifier means is to be changed, said indication

comprising the current and the new gain levels of the amplifier means. Each phase change value of the storage means corresponds to the change of the phase of the output power of the amplifier means when the gain level of said
5 amplifier means is changed from a first reference level, such as the lowest gain level, to a second predetermined gain level. Changing the gain level of the amplifier means will change the output power to a predetermined level. In alternative embodiments of the device according to the
10 invention, said device comprises a temperature sensing means and/or a frequency indicator, wherein the device is adapted to compensate for temperature and/or frequency dependent phase-shifts.

Another object of the invention is to provide a
15 method for compensating phase-shifts of an output signal from a transmitter chain of an electronic equipment, said phase-shifts occurring as time discrete phase-jumps in response to changing the output power of the output signal. Also, it is an object of the invention to provide a method
20 for compensating for temperature dependent phase-shifts of the output signal. Still another object is to provide a method for compensating for frequency dependent phase-shifts of the output signal.

These objects are achieved by a method for
25 predistorting an input signal at an amplifier means comprising the steps of: retrieving from a storage means phase change values; calculating a phase offset value based on the retrieved change values; and adding the phase offset value to the input signal. In an alternative embodiment a
30 temperature or a temperature interval is derived, and temperature dependent phase change values are retrieved from the storage means, wherein a temperature dependent phase offset signal is added to the input signal. In still en alternative embodiment a frequency or frequency interval
35 is derived, and frequency dependent phase change values are

retrieved from the storage means, wherein a frequency dependent phase offset signal is added to the input signal.

It is another object of the invention to provide an electronic equipment capable of compensating for phase-
5 . shifts of the output power of an output signal from a transmitter chain of the electronic equipment, said phase-shifts occurring as time discrete phase jumps in response to changing the output power.

This object is achieved by an electronic equipment
10 comprising the device according to the invention. In one embodiment, the equipment is a mobile terminal, a pager or a communicator. In another embodiment, the electronic equipment is a mobile telephone.

An advantage of the present invention is that it is
15 possible to implement the device in the digital domain, wherein the electronic equipment will consume almost no extra power. Also, if the storage means is a rewritable memory, the stored phase change values may be altered in the future to meet technology changes in the communication
20 system.

Further preferred features of the invention are defined in the dependent claims.

It should be emphasized that the term "comprises/comprising" when used in this specification is
25 taken to specify the presence of stated features, integers, steps, components or groups thereof.

Brief Description of the Drawings

In the following the present invention will be
30 described in relation to some embodiments and accompanying drawings, in which:

Fig. 1 illustrates a mobile terminal comprising the device according to the invention, and a base station;

Fig. 2 is a block diagram of a wave form generator
35 connected to the device according to the invention;

Fig. 3a illustrates a first embodiment of a look-up table according to the invention;

Fig. 3b illustrates a second embodiment of a look-up table according to the invention;

5   Fig. 3c illustrates a third embodiment of a look-up table according to the invention;

Fig. 4 is a flow chart of a method for deriving phase change values stored in any of the look-up tables illustrated in Fig 3a-3c; and

10   Fig 5 is a flow-chart of a method according to the invention for adding a phase offset signal to the input signal at an amplifier means.

Detailed description of embodiments

15   Various mobile communication systems utilize fixed base stations for communicating with mobile terminals via a wireless interface. Such systems include code division multiple access (CDMA) systems, such as the wide band multiple access (WCDMA) system employed in the universal

20   mobile telecommunication system (UMTS).

Fig. 1 illustrates an electronic equipment embodied as a mobile terminal 1, which according to the invention comprises a device 46 for predistorting an input signal at an amplifier of a transmitter chain of the mobile terminal

25   1. The device of the invention is adapted to add a phase offset to the input signal in response to a change of the output power of the mobile terminal. As is understood, the electronic equipment may take other forms, such as a mobile telephone, a pager, or a communicator, without departing

30   from the scope of the invention. However, for convenience reference will be made to a mobile terminal 1 throughout this description. Further, the mobile communication system comprises at least one base station 2, with which the mobile terminal 1 may communicate speech and data according

35   to a predetermined protocol over a wireless link 3. The

mobile terminal 1 comprises a man machine interface, with
which a user of the mobile terminal 1 may operate said
terminal. The man-machine interface may comprise, but is
not limited to, a display 10, a keypad 11, a microphone 12,
5   and a loudspeaker 13. Further, the mobile terminal
comprises an antenna 14 for transmitting signals to the
base station 2. The antenna 14 is connected to the
transmitter chain within the mobile terminal 1.

    Fig. 2 illustrates a waveform generator 20 being part
10   of the transmitter chain of the mobile terminal 1
comprising the device according to the present invention.
The waveform generator 20 comprises first and second
transmitter filters 21, 22 for filtering the in-phase (I)
component and the quadrature (Q) component of a base band
15   signal, respectively. Further, a first mixer 23 is provided
prior to the filters 21, 22 for mixing the base band signal
with the scrambling code of the mobile terminal 1. The
waveform generator 20 is adapted to generate a base band
signal to be supplied as the input signal to an amplifier
20   means 30 via a RF (radio frequency) modulator 31.

    To provide changing of the output power of the output
signal of the transmitter chain the amplifier means 30 is
in one embodiment a variable gain amplifier (VGA). The gain
of the variable gain amplifier may e.g. be set according to
25   predetermined levels in order to set the output power level
of the transmitter to meet requirements of different
specifications. Power levels and classes are e.g. specified
in the third generation partnership project (3GPP)
specification TS 25.101, which is incorporated herein by
30   reference. However, the exact number of power classes or
power levels of the output power is not important for the
present invention, wherein any number of classes or levels
may be implemented.

    A power controller 40 sets the gain levels of the
35   amplifier means 30 to keep the output power at a desired

level. Consequently, the power controller 40 is connected
to the amplifier means 30 to control the output power of
the amplifier means in any number of predetermined levels.
The exercise of the control of the gain levels of the
5   amplifier means 30 to adjust the output power may be
executed in a number of different ways. In open loop power
control, the mobile terminal 1 determines an estimate of
the path loss between the base station 2 and the mobile
terminal 1 by measuring the received signal strength at the
10 mobile terminal 1. An automatic gain control (AGC)
circuitry (not shown) within a receiver chain 45 of the
mobile terminal 1 provides a rough estimate of the
propagation loss for each mobile terminal 1. The smaller
the received power the larger the propagation loss, and
15 vice versa. The transmit power, i.e. the output power, of
the mobile terminal 1 is in one embodiment determined from
the equation:

mean output power (dBm)=-mean input power (dBm) + offset
power + parameters.
20 The offset power is e.g. -73 dB for the 800 MHz band mobile
terminal and -76 dB for the 1900 MHz mobile terminals in
the IS-95 standard (US CDMA system).

The desired output power level is then supplied by
the receiver chain 45 to the power controller 40. The
25 parameters are used to adjust the open loop power control
for different cell sizes and different cell effective
radiated powers (ERP) and receiver sensitivities. The
parameters are initially transmitted on the synchronization
channel between the mobile terminal 1 and the base station.
30   In another embodiment closed loop power control is
utilized, wherein a transmit power control (TPC) command is
received in the downlink by the receiver chain 45 of the
mobile terminal 1. Said command is derived by the base
station 1 based on the received signal strength of the
35 signal from a specific mobile terminal 1. The power

controller 40 is connected to the receiver chain 45 in order to receive the TPC commands and set the gain level of the amplifier means 30 accordingly. The receiver chain 45 does not form any part of the present invention, and is

5   therefore not further disclosed herein. In one embodiment of the invention, the power controller 40 forms part of the amplifier means 30.

As discussed above, the change of the gain level of the amplifier means 30, and consequently the output power,

10   will add a phase-shift to the output power of the output signal from the amplifier means 30. The phase-shift will occur as a time discrete phase-jump of the output power in response to the change of the output power. To compensate for such phase-shifts, a phase offset signal is added to

15   the base band signal, which is generated by the waveform generator, by means of the device 46 according to the invention for predistorting the input signal at the amplifier means 30. In one embodiment, the phase offset signal is a complex value having amplitude corresponding to

20   1 and a phase value corresponding to a phase offset value, which will be described below. Therefore, the device 46 comprises a phase offset adding means 50, such as a digital multiplier or a complex multiplier, that mixes the base band signal from the waveform generator 20 with the phase

25   offset signal. In the embodiment illustrated in Fig. 2, the phase offset adding means 50 is provided after the waveform generator, i.e. after the first and second transmitter filters 21, 22. However, in alternative embodiment, the phase offset adding means 50 is a part of the waveform

30   generator 20, wherein the phase offset adding means 50 is provided before the transmit filters 21, 22. As is understood, also other positions of the phase offset adding means 50 is possible within the scope of the invention, as long as the phase offset may be added to the input signal

35   at the amplifier means 30.

The device 46 according to the invention further comprises a storage means 51 and an offset controller 52. The storage means 51 is in one embodiment a memory, wherein at least one value of the change of the phase of the output

5. power for different gain levels of the amplifier means 30 is stored in a look-up table 53a, as will be further explained in the following. In one embodiment, the storage means 51 is a rewritable memory, wherein the phase change values stored in said memory may be substituted. In another

10 embodiment, the storage means 51 is a read only memory (ROM), wherein the values of the look-up table 53a are stored by the manufacturer of the mobile terminal 1 according to a predetermined specification.

Fig. 3a illustrates a first embodiment of the look-up

15 table 53a stored in the storage means 51. The look-up table 53a comprises columns, wherein different gain levels G_i $(G_i=G_1...G_n)$ of the amplifier means 30 is stored in a first column, and phase change values C_i $(C_i=C_1...C_n)$ associated with each gain level are stored in a second column.

20 Consequently, phase change value C_1 corresponds to a change of the phase of the output power when the gain is changed from gain level G_0 to gain level G_1 etc. A phase change value will not be stored for the lowest gain level G_0. In one embodiment, each phase change value is a digital phase

25 value, which may be retrieved by the offset controller 52. Consequently, the storage means 51 is connected to the offset controller 52 being connected to the power controller 40. In an alternative embodiment, the power controller 40 and the offset controller 52 are provided as

30 one controller providing the functions of the separate controllers 40, 52.

When it is decided that the gain level of the amplifier means 30 should be changed, i.e. increased or decreased as indicated by the open or closed loop power

35 control as described above, the power controller 40

transmits a gain control signal to the amplifier means 30
instructing said amplifier means 30 to change its gain
level. Also, the power controller 40 transmits a gain
change indication signal to the offset controller 52
5   indicating that the gain of the amplifier means 30 is to be
changed. The gain change indication signal comprises
information of the new gain level of the amplifier means
30. In response thereto, the offset controller 52 retrieves
from the storage means 51 the phase change values
10 corresponding to the new gain level by addressing the
storage means by means of the new gain level. Then, the
phase offset value is outputted, as will be explained
below.

In an alternative embodiment the output power, and
15 consequently the gain level, of the amplifier means 30 is
compensated for temperature dependent phase-shifts in
connection with the gain level dependent phase-shift.
Therefore, a temperature sensing means 60, such as a
temperature sensor, is connected to the offset controller
20 52.

Fig. 3b illustrates one embodiment of a second look-
up table 53b comprising phase change values being dependent
on the gain level of the amplifier means 30 as well as the
temperature. The temperature may be divided into different
25 temperature intervals T_i, such as 0-5 °C, 5-10 °C etc., to
limit the needed storage space. The specific number of
temperature intervals $(T_1...T_n)$ has to be tested and
evaluated in each specific case. As in the embodiment
illustrated in Fig. 3a, the look-up table 53b comprises
30 columns, wherein different gain levels of the amplifier
means 30 is stored in a first column, and the associated
phase change value is stored in a second column. However,
here the look-up table 53b comprises a third dimension,
wherein the gain levels G_i and the associated phase change
35 values C_i are stored for each temperature interval T_i. In

this embodiment, the offset controller 52 has to provide
both information of the second, i.e. the new, gain level of
the amplifier means 30 as well as temperature information
to the look-up table 53b to retrieve the correct phase

5   change value, wherein the temperature value or the
temperature interval value is an index to address the look-
up table 53b together with the new gain level.

In another embodiment, the device 46 according to the
invention compensates for frequency dependent phase-shifts

10   or frequency band dependent phase-shifts of the output
signal of the amplifier means 30. In this embodiment, the
device 46 according to the invention comprises a frequency
indicator 70 connected to the offset controller 52, which
may divide each specific frequency into different frequency

15   intervals F_i ($F_i=F_1...F_n$). The frequency indicator indicates
the operating frequency and/or the operating frequency band
of the mobile terminal 1. Fig. 3c, illustrates a look-up
table 53c comprising data having phase shift change values
C_i depending on both gain level G_i of the amplifier means

20   30 as well as the frequency intervals F_i. In this
embodiment, the offset controller 52 has to provide both
information of the first and second gain levels of the
amplifier means 30 as well as frequency interval
information to the look-up table 53b to retrieve the

25   correct phase change values, wherein the frequency value or
the frequency interval value is an index to address the
look-up table 53c together with the new gain level of the
amplifier means 30.

In still another embodiment the device 46 according
30   to the invention compensates both for frequency dependent
and temperature dependent phase-shifts in addition to gain
level dependent phase-shifts. In this embodiment, a number
of look-up tables are provided, wherein each table
corresponds to either the embodiment shown in Fig. 3b or
35   3c, and being valid in a specific temperature interval or a

specific frequency interval. The specific look-up table may be addressed, by means of the temperature interval or the frequency interval information, to accessing the specific phase change values corresponding to certain first and

5   second gain levels and a certain temperature interval or frequency interval.

The phase change values to be stored in the storage means 51 may be defined according to the steps illustrated in the flow chart of Fig. 4 and described in the following:

10   First, in step 100 supply an input signal generated by a waveform generator 20 without any phase offset adding means 50 according to the invention, or with the phase of phase offset set to 0, to the amplifier means 30 being set to the lowest gain level G_0. Keep the temperature constant

15   at a predetermined level, such as room temperature.

In step 101, measure and temporarily store the phase of the output power from the amplifier means 30 to provide a phase reference value.

In step 102, increase the output power with a

20   predefined value, such as 1 dB, by increasing the gain level of the amplifier means 30.

Then, in step 103 measure the phase of the output power from the amplifier means 30.

In step 104, calculate the value of the change in

25   phase, between the changed phase measured in step 103 and the phase reference value calculated in step 101, and store said change value in the look-up table 53a of the storage means 51 at the gain level set in step 102 as a corresponding phase change value C_i. Consequently,

30   increasing the gain level from the first, or lowest, gain level G_0 to the second gain level G_1 will generate a first phase change value C_1 corresponding to the second gain level G_1.

In step 105, decide whether the gain level of the

35   amplifier means 30 has reached its highest gain level G_n.

If not, the procedure is returned to step 102 to derive a subsequent phase change value C_{i+1}. However, if the decision in step 105 if affirmative, in step 106 the procedure is ended.

5   The method illustrated in steps 100-106 of Fig. 4 may be repeated for different temperatures or temperature intervals, wherein the temperature chosen is preferably in the middle of the temperature interval if temperature dependent phase offset signals should be provided. This

10   will generate a look-up table 53b according to Fig. 3b. As is understood, the method in step 100-106 may also be repeated for different operating frequencies or operating frequency intervals of the mobile terminal 1, wherein the operating frequency is kept constant throughout one cycle,

15   100-106. The chosen operating frequency in each frequency interval is preferably chosen in the middle of the frequency interval. The procedure is then repeated for any required operating frequency or frequency interval. Also, the procedure in Fig. 4 may equally be repeated for

20   different temperature intervals and frequency intervals to generate change phase change values being both frequency and temperature dependent.

      In CDMA technology information data is sent to the base station 2 in slots having a small time gap between

25   subsequent slots. During the time gap no information data is transmitted to the Base station. The control of the gain level of the amplifier means 30 is preferably executed during the time gap as the changing of the gain level will generate a small transient in the output signal although

30   the phase offset signal is added to the input signal. However, if the changing of the gain level of the amplifier means 30 and the adding of the phase offset signal to the input signal at the amplifier means 30 is synchronized during the time gap the transient will not be detrimental,

35   as no information data is transmitted.

Fig. 5 illustrates the method for predistorting the
input signal according to the invention for compensating
for phase changes due to a gain level change of the
amplifier means 30. In the preferred embodiment, the steps
5 according to the method are executed in the time gap
wherein no transmission of information data is provided.
The needed phase compensation of the input signal at the
amplifier means 30 is calculated by the offset controller
52 and supplied as the phase offset signal to the phase
10 offset adding means 50. In a first step 200, an indication
to change the output power to a certain level, such as the
TPC command, is received by the power controller 40. In
step 201, the new gain level of the amplifier means 30 is
determined based on the indication received in step 200. In
15 step 202, in response to determining the new gain level, or
changing the gain level, the new gain level of the
amplifier means 30 is indicated by the power controller 40,
i.e. supplied to the offset controller 52, which will be an
index for addressing the lookup-table 53a of the storage
20 means comprising gain levels and associated phase values.
Each gain level stored in the look-up table have an
associated phase value. Therefore, the offset controller 52
will retrieve a phase value corresponding to the new gain
level of the amplifier means 30.

25   In step 203, if the offset signal should compensate
for temperature and/or frequency dependent phase-shifts,
the offset controller 52 obtains the temperature supplied
by the temperature sensing means 60, and/or the frequency
or the frequency band supplied by the frequency indicator
30 70. Then, the temperature interval and/or the frequency
interval may be derived. If the temperature and/or
frequency are not needed, step 203 is omitted. Then, in
step 204 the new gain level of the amplifier means 30
together with the frequency/frequency interval and/or the
35 temperature/temperature interval are used to address the

storage means 51 to retrieve an associated temperature/frequency dependent phase value, i.e. a change value C_i, which corresponds to the new gain level. The new gain level, possibly together with the temperature (or

5   temperature interval) and the frequency (or frequency interval or band), acting as an index to address the look-up table 53a, 53b, 53c are supplied to the storage means 51, which returns the demanded phase change value. However, if the new gain level of the amplifier means 30 is the

10   basic gain level, no change value needs to be retrieved, as the change value relating to the basic gain level is known to be zero. However, as is understood, a change value may also be stored for the basic gain level. Finally, in step 205 the power controller 40 supplies the new gain level to

15   the amplifier means 30, which will provide the output power level indicated by the change indicator. Also, the offset controller 52 supplies the value of the phase offset signal to the phase offset adding means 50, which will add said offset to the input signal generated by the waveform

20   generator. If the gain level is changed and the value of the phase offset signal is added to the input signal at the amplifier means 30 during the time gap, no detrimental phase jump will be added to the output signal from the mobile terminal 1.

25   The present invention has been described in some embodiments. However, the scope of the invention should not be limited to the above-described embodiments, but is best defined by the following independent claims. Furthermore, the term "comprising" does not exclude other elements or

30   steps, the terms "a" and "an" do not exclude a plurality and a single processor or other unit may fulfill the functions of several of the units recited in the claims. The function of the offset controller 52 may e.g. be implemented as software comprising computer readable

35   instructions for carrying out the functions of said

controller when executed by a processing unit, such as the central processing unit of the mobile terminal 1.